LEAD AND CADMIUM REMOVAL IN SYNTHETIC WASTEWATER USING CONSTRUCTED WETLAND

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DECLARATION

I declare that this thesis entitled **"LEAD AND CADMIUM REMOVAL IN SYNTHETIC WASTEWATER USING CONSTRUCTED WETLAND"** is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:……………………………………….
Name of Candidate	: Mohd Shahrel B Baharudin
Date	: 16th May 2008

DEDICATION

Special Dedication to my beloved mother (Norhan) and father (Baharudin), for their love and encouragement.

And,

Special Thanks to my friends, my fellow course mates and all faculty members. For all your care, support and best wishes.

Sincerely,
Mohd Shahrel B Baharudin

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ABSTRACT

Heavy or toxic metals are harmful to humans and other organism even in small quantities. This research focused on the removal efficiency of the heavy metals (lead and cadmium) using constructed wetland system. Constructed wetlands are the low cost engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters. In addition, constructed wetland treatment had demonstrated the good capacity in treating the wide range of wastewaters including the hazardous industrial waste. In this research, the free water surface constructed wetland was conducted in the batch mode system and loaded with *Pistia stratiotes* (water lettuce) in order to study the removal efficiency of cadmium and lead elements. From the study, it was found that the *Pistia stratiotes* is an aquatic plant that growing rapidly and also a high biomass crop with an extensive root system that can enhance the heavy metals removal. There were two parameters studied in this research which were varying in number of plant, and varying pH conditions. The removal of lead and cadmium in the constructed wetland were increased when the numbers of plant increased. The constructed wetland containing 15-plants recorded the highest removal with 99.28% for lead removal and 65.89% for cadmium removal. For the pH condition experiment, the neutral condition (pH = 7) showed the better removal compared to the base and acidic conditions. As a conclusion, constructed wetland system with wetland plant (*Pistia stratiotes*) showed good removal efficiency for lead and cadmium from the industrial wastewater.

ABSTRAK

Logam berat atau logam toksik adalah sangat berbahaya kepada manusia dan organisma lain walaupun di dalam kuantiti yang kecil. Kajian yang dilakukan ini telah memfokus terhadap kecekapan penyingkiran logam berat (plumbum dan kadmium) dengan menggunakan tanah bencah buatan. Tanah bencah buatan merupakan sistem berkos rendah yang telah diubahsuai dimana ianya direka dan dibina untuk menjalankan proses semulajadi yang melibatkan tumbuh-tumbuhan tanah bencah, tanah, serta himpunan mikrob tanah bencah itu sendiri bagi membantu dalam rawatan sisa cecair. Tambahan pula, rawatan ini telah menunjukkan hasil yang baik di dalam merawat pelbagai jenis sisa cecair termasuklah sisa industri yang sangat berbahaya. Di dalam kajian ini, kaedah rawatan tanah bencah jenis permukaan air bebas telah dijalankan dalam keadaan sistem berkelompok serta akan ditumbuhkan dengan *Pistia stratiotes* (kiambang) bagi mengkaji kecekapan penyingkiran elemen kadmium serta plumbum. Kajian sebelum ini menunjukan bahawa *Pistia stratiotes* merupakan tumbuhan yang tumbuh dengan pantas serta merupakan tumbuhan berjisim biologi tinggi yang mempunyai sistem akar bersambungan bagi menggalakan proses menyingkiran logam berat. Parameter yang telah dikaji di dalam kajian ini adalah perbezaan dari segi jumlah tumbuhan, serta perbezaan pH. Tanah bencah buatan yang mempunyai 15 pokok telah mencatatkan penyingkiran yang paling tinggi iaitu 99.82% untuk penyingkiran plumbum manakala 65.89% untuk kadmium. Bagi eksperimen pelbagai pH pula, tanah bencah buatan pada pH neutral (pH = 7) menunjukkan peyingkiran logam yang baik berbanding dengan kondisi berasid dan beralkali. Kesimpulannya, sistem rawatan tanah bencah dengan menggunakan tumbuhan tanah bencah tertentu seperti (*Pistia stratiotes*) menunjukan kecekapan penyingkiran yang baik terhadap elemen plumbum dan kadmium daripada sisa cecair industri.

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LIST OF SYMBOLS

$(C_2H_5)_4Pb$	-	Tetraethyllead
µM	-	Micromolar
AA	-	Atomic absorption
Al	-	Aluminum
As	-	Arsenic
Ba	-	Barium
BOD_5	-	Biochemical oxygen demand
Cd	-	Cadmium
$Cd(NO_3)_2$	-	Cadmium nitrate
Co	-	Cobalt
COD	-	Chemical oxygen demand
Cu	-	Copper
CWs	-	Constructed wetlands
Fe	-	Ferum
FWS	-	Free water surface
HCl	-	Hydrochloric acid
HNO_3	-	Nitric acid
L	-	Liters
mM	-	Milimolar
Mn	-	Manganese
NaOH	-	Sodium hydroxide
Ni	-	Nickel
Pb	-	Lead
$Pb(NO_3)_2$	-	Lead nitrate
$PbO{\cdot}PbSO_4$	-	Monobasic lead sulfate
PbS	-	Lead sulfide
$PbSO_4$	-	Lead sulfate

Se	-	Selenium
SF	-	Surface flow
Sr	-	Strontium
TKN	-	Total Kjeldahl nitrogen
V	-	Vanadium
Zn	-	Zinc

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater (Vymazal, 2007). In the simple phrase, constructed wetlands can be defined as “man-made”, “engineered” or “artificial” wetlands. Despite treating the wastewater, constructed wetland also can be an attractive natural landscape where wildlife builds habitat and for human visit.

Much interest has been focused on constructed wetlands for removing toxic metals from wastewater in recent years (Raskin and Ensley, 2000). There are four aspects on how the heavy metals are accumulated by plants in constructed wetland systems, which are; bioaccumulation, phytoextraction, phtostabilation and rhizofiltration.

Constructed wetlands are being considered as a sustainable, low-investment and low maintenance cost technology that can complement or replace conventional water treatment (Tack *et al.*, 2007). Nowadays, many industrial investors are looking to fix the constructed wetland systems into their wastewater management system. They noticed that the constructed wetland can minimize the energy consumption and operational cost.

Recent studies show that constructed wetlands can treat the wide range of wastewaters including the hazardous industrial waste. The industrial wastewater usually contains a certain amount of heavy metals like lead and cadmium. These heavy metals are the hazardous pollutants to human and animals even in the small portion of them. Cadmium is discharged to the environment by the metal plating and battery industries. While, the higher lead concentration can be find in the petroleum refinery and steelwork industrial effluent.

The selection of appropriate wetland plant species in constructed wetland is important in making the constructed wetland functioned effectively in heavy metals removal. Plant species have the variety of capacity in removing and accumulating heavy metals (Zayed *et al.,* 1998). Therefore, some plant uptakes on heavy metals were varied based on their species. Water-lettuce (*Pistia stratiotes*) is an aquatic plant that growing rapidly and also a high biomass crop with an extensive root system that able enhance the heavy metals removal.

1.2 Objective

The objective of this study is to investigate the removal efficiency of the heavy metals (lead and cadmium) using constructed wetland system.

1.3 Scope of Study

The study was focused on the effect of constructed wetland in treating industrial wastewater. In this experiment, the constructed wetland was designed with the same plant species, which is water lettuce (*Pistia stratiotes*) species. This experiment also focused on the lead and cadmium removal from industrial wastewater using constructed wetland. The treatment was conducted for 7 days. The scopes for this study were:

1. To construct the wetland with water lettuce (*Pistia stratiotes*) plant species.
2. To focus on the treatment of lead and cadmium containing wastewater.
3. To study the removal efficiency of lead and cadmium when:
    a. The numbers of plants are increased.
    b. The pH is varies.

The experiment was carried out at the Faculty of Chemical Engineering and Natural Resources Laboratory, Universiti Malaysia Pahang.

1.4 Problem Statement

Toxic heavy metals in air, soil, and water are global problems that are a growing rapidly in the development area. Industrial wastes that contain heavy metals cause an unreasonable risk to human health and safety, property, and the environment.

The exposure of heavy metals can cause disorder to the human body system. Furthermore, this type of waste has the potential to contribute in mortality and increase the serious irreversible illness. Acute lead poisoning in humans causes severe failure in the kidneys, reproductive system, liver, brain and nervous system. Cadmium exposure is also harmful to human as it causes high blood pressure, kidney damage and cancer.

The technology for treatment and disposal of the industrial wastes must be efficient in order to overcome this problem. Constructed wetland is an economic treatment system that has received much attention recently. In this system, wetland plants play an important role in heavy metals removal. Therefore, appropriate selection of wetland plant species in constructed wetland can exploit the removal potential of heavy metals by wetland plants (Liu *et al.,* 2007).

The approach in managing a constructed wetland is constantly the vital issue that consecutively makes this system functioned efficiently in removing the heavy metals. Thus, the well managed constructed wetland through the proper treatment makes this system as an alternative method in treating industrial wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Wetland

Wetland are areas where water covers the ground surface or is present at the ground surface for varying periods of time during the year. The prolonged presence of water creates conditions that favor the growth of specially adapted plants (hydrophytes) and promote the development of characteristic wetland (hydric) soils. Although wetlands are often wet, a wetland might not be wet year-round. In fact, some of the most important wetlands are only seasonally wet. Wetland occur at the interface between land and water and are transition zones where the flow of water, the cycling of nutrients, and the energy of the sun meet to produce a unique ecosystem. The wetland ecosystem is characterized by unique hydrology, soils, and vegetation that make these areas as the important features of a watershed. Wetlands are among the most productive ecosystem in the world, comparable to rain forests and coral reefs, as well as they perform a variety of ecological functions. The combination of shallow water, high levels of nutrients, along with primary productivity is ideal for the development of organisms that form the base of food web and feed many species of fish, amphibians, shellfish, and insects. Wetlands are points of ground-water recharge, absorb water, take up airborne pollutants, ease floodwater, control erosion, cycle minerals (nitrogen), produce organic matter through carbon fixation, and provide feeding refuge and reproductive habitats for a wide variety of fish and wildlife (Chin, 2006).

2.2 Natural Wetland

Natural wetlands can be broadly classified as either coastal wetlands or inland wetlands, where coastal wetlands are influenced by alternate floods and ebbs of tides while inland wetlands are nontidal. Coastal wetlands may be further categorized as either marine or estuarine wetlands (Chang, 2002), depending on whether they are adjacent to an open ocean or adjacent to an estuary. In contrast to coastal wetlands, inland wetlands are most common on floodplains along rivers and streams (riverine wetlands), in isolated depressions surrounded by dry land (palustrine wetlands), along littoral zones of lakes and ponds (lacustrine wetlands), and in other low-lying areas where the ground water intercepts the soil surface of where precipitation sufficiently saturates the soil. Riverine and lacustrine wetlands are sometimes collectively referred to as riparian wetlands. Wetlands are typically classified as marshes, swamps, bogs, or fens (Chin, 2006).

2.3 Constructed Wetland

Constructed wetlands (CWs) are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters. They are designed to take advantage of the same processes that occur in natural wetlands, but possesses within a more controlled environment. CWs for wastewater treatment may be classified according to the life form of the dominating macrophyte into systems with free-floating, rooted emergent and submerged macrophytes (Brix and Schierup, 1989).

Constructed wetlands have traditionally been used for the treatment of domestic along with municipal sewage from both separate and combined sewerage. However, since the late 1980s CWs have been used for many other types of wastewater, including agricultural wastewaters, mine drainage, food processing wastewaters, heavy industry wastewaters, landfill leachate and runoff waters efficiently. For more examples, refer to Table 2.1. Since that, constructed wetlands are being considered as a sustainable, low-investment and low maintenance cost technology that can complement or replace conventional water treatment (Tack *et al.*, 2007).

Table 2.1 : Examples of applications and efficiency of wetlands for quality improvement of water (Otte and Jacob, 2006)

Type of pollutant	Efficiency (% removal)
Macronutrients	
Ammonium-N	16-67
Nitrate/Nitrite	40
Total Kjeldahl nitrogen (TKN)	49-81
Organic nitrogen	82
Soluble Reactive Phosphate (SRP)	56
Total-P (TP)	44-68
Metals and Metalloids	
Al	81-97
As	65
Ba	70-95
Cd	58-71
Co	39-98
Cu	49-65
Fe	91-97
Mn	91-99
Ni	22-67
Se	69
Sr	24-51
Zn	52-95
V	100
Organic compounds, including explosives	63-100
Coliform bacteria	26-98
Eggs of human parasites	94-100
COD	81
BOD_5	72-89
Suspended solids	43-94